ICT IN THE SERVICE OF GOOD ARCHITECTURE DESIGN: WITH SPECIAL REFERENCE TO SPORTS FACILITIES AND ARENAS

Maver Tom, Petric Jelena

The Mackintosh School of Architecture, Glasgow School of Art, Glasgow, UK

The Design Research Society (DRS) in the UK and the Design Methods Group (DMG) in the USA came into existence around the same time in the 1960's. For the first time intellectual endeavour was focused on the complex human activity of design decision–making. John Christopher Jones established at Manchester University a Masters course in Design and published the influential book 'Design Methods' (Jones.1992). He later became the first professor of Design in the innovative Open University in the UK.

Rittell in Germany and Jones, along with Bruce Archer, Sydney Gregory and others in the UK began to develop what Herbert Simon, in his 1968 book 'The Sciences of the Artificial', called "*a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process*" (Simon. 1968)

The notion that all academic thought lay along an axis from the **sciences** to the **humanities** was challenged. Instead, it was suggested by Archer (Archer 1976)) that academic thought could be plotted as a triangle with **humanities**, **science** and **design** at its apexes **(Figure 1).**

Figure 1. The argument to elevate Design as a discipline equal to the Sciences and the Humanities

For science, the prime language is **mathematics** and for humanities it is **natural language**, the language of design, it was proposed, is **modelling**.

Around the same time, - the mid 1960's- interest was growing in the idea of what is now know as 'post occupancy appraisal' (POA) of buildings. The building boom in the UK after the second world war had produced some disastrous outcomes and there were clearly lessons to be learnt by studying the performance (or rather the lack of performance) of existing buildings.

The building industry, at 12% of gross Domestic Product, was northern Europe's second largest single industry employing (directly or indirectly) 1 in 12 of the working population. Yet despite it's scale and importance in the national and regional economy, the building industry was under-developed and dis-aggregated. In the UK for instance, only 6% of contacting firms employed 7 or more people; 50% of architectural practices employed 2 or fewer professionals. The research and development budget of the industry was, and remains, a meagre half of one percent of turnover. The professional education provision was highly fragmented and Continuing Profession Development opportunities were very limited. Overall the labour force was poorly qualified.

This had a serious consequence for the quality of the built environment. Conservative estimates suggestwas that remedial treatment of building defects costs the UK upwards of £1,000 million per annum (excluding normal maintenance); some 50% of these defects, it is judged, could have been obviated by better **design**. In a high proportion of post-war buildings, energy consumption was profligate; UK Department of Energy figures suggested a potential saving of up to 50% through better design of new buildings and an additional 25% through appropriate design intervention in the existing stock of buildings.

In 1967 Professor Tom Markus set up, in the Department of Architecture and Building Science at the University of Strathclyde, a multi-disciplinary research team – the Building Performance Research Unit (BPRU) – to develop tools for the appraisal of buildings in use. These tools, and their use, for "post occupancy appraisal" (POA), were described in the seminal book Building Performance (Markus et al. 1972).

While the value of POA was recognised, a bolder notion emerged: could the design methodologies from the DRS and the DMG be deployed during the course of the design activity to achieve an outcome that was more fit for purpose, more cost-effective and more sustainable?

Although building design has much in common with product design, there is a significant difference. In product design, the *modus operand*' is to construct, and progressively refine, a *physical prototype* prior to the production run – a methodology impractical in large capital items such as buildings. What was needed, then, was a new paradigm: what we would today call a *virtual prototype*.

In the vanguard of efforts to achieve such a paradigm was the Architecture Machine Group (and subsequently the highly influential Media Lab) at MIT and the Architecture and Building Aids Computer Unit, Strathclyde (ABACUS) in the University of Strathclyde. Nicholas Negroponte's book, 'The Architecture Machine' (Negropontes 1970) was inspirational: he dedicated the book "To the first machine that can appreciate the gesture". In the same year, Maver, Director of the Architecture and Building Aids Computer Unit, Strathclyde (ABACUS), a research group that had grown out of the BPRU, published "A Theory of Architectural Design in Which the Role of the Computer is Identified" (Maver. 1970).

The *virtual prototype paradigm* proposed by ABACUS, was captured in a simple diagram (Figure 2). Here, the designer proposes a design solution; appropriate computer-based modelling software predicts the cost and performance characteristics (the "fingerprint"); this, the, is assessed and evaluated, thereby informing the next design iteration.

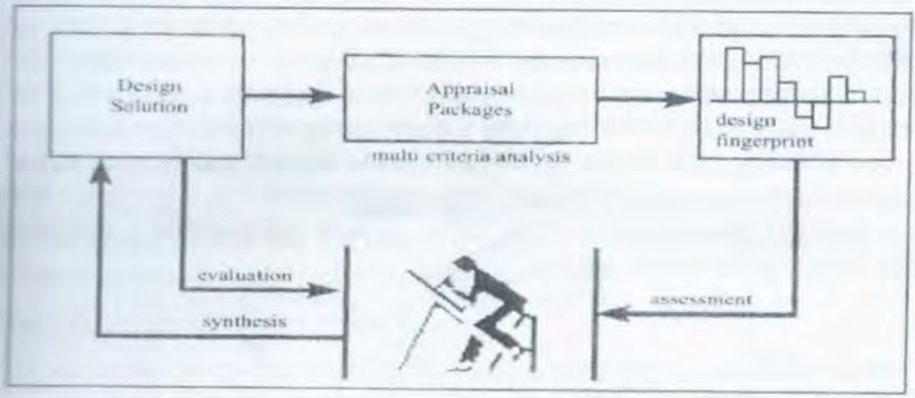

Figure 2. An early diagram representing the virtual prototype paradigm

At that time (1970) Strathclyde University had only one main-frame computer; programs and data could be entered only in binary form using paper tape or punched cards. Any prototype building had, therefore, to be "described" in terms of the x and y coordinates of every geometric vertex (for plan layouts) or x, y and z coordinates (for 3D forms); explicit instructions (in a language called FORTRAN – short for Formula Translation) specified which coordinates were joined by lines, which lines formed planes and which planes made up volumes; there was neither graphical input nor output. It seem, in retrospect, a miracle that that the fledgling activity of specifying building form continued!

Nonetheless, against the odds, by 1970, papers were being published which described the process of appraising a simple building in terms of its cost (capital cost, recurring life-cycle cost) and its performance (daylight levels, energy consumption, plant size, etc). By 1973 the emergence of pen-plotters, combined with innovative algorithms, made it possible to produce drawn plans and 3D ("wire-line") perspectives; affordable graphical input devices were also becoming available. Overnight, the architectural profession - highly suspicious of the idea that computers could have anything less than a deleterious influence on design quality - embraced the technology as a means of automating production drawings; the emphasis for the next 5/6 years, shifted (some would regret) from better *product* to more efficient *production*.

The 1980's and 1990's saw the evolution of increasingly sophisticated models of the energy behaviour in buildings (Clarke and Maver. 1991) It became possible to demonstrate that the simplistic calculations in currency at that time were, at best, woefully inaccurate and at worst positively misleading. Figure 3 compares the outcome of calculations made of the energy consumption in a standard building by the simplistic hand calculations at that time approved by the Royal Institute of British Architects (the 'broken' lines) with those calculations using the sophisticated computer-based model developed by ABACUS (Clarke J.A and Maver, T.W. 1991). Because the simplistic calculation was unable to take account of varying solar gain throughout the year, it suggests an optimum solution of zero glazing; or, in the hands of a more intelligent user, *maximum* consumption of energy at 60% glazing. The sophisticated computer-based model that based on the new generation of energy models deals in first principles with thermo-fluid and thermodynamic flux, shows exactly the opposite – *minimum* energy consumption at 60% glazing.

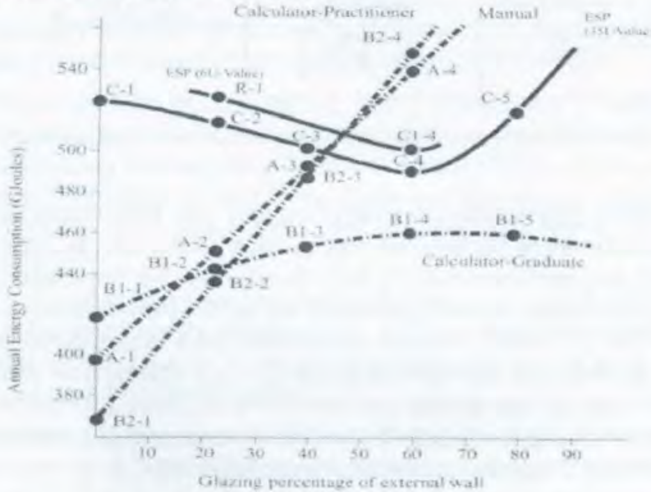

Figure 3. Comparison of the results from a simplistic hand calculation (broken lines) with those of a "first principles" computer-based model (full lines)

Based on the new generation of energy models, an energy design advice scheme for architects pioneered by the Royal Incorporation of Architects, yielded certified annual and recurring saving in energy equivalent to millions of Euros (McElroy et al. 1997)

The success of advanced computer-based models of the complex energy behaviour of buildings spurred the development of computer-based models of how light (and subsequently sound) from multiple sources could be traced within complex building geometries to provide realistic experiences of the *quality* of the built environment

This period also saw rapid development of software for photorealistic colour imaging of both the exterior and interior of buildings and the subsequent animation of these images to afford virtual "journeys" around and through buildings that were still on the drawing board. Increased computing power allowed groups of buildings, settlements and ultimately entire cities to be modelled.

The early pioneering work of the MIT Media Lab had led to the now ubiquitous multimedia computer-based documents seem-lessly combining text, drawings (hand and computer generated). photography, video, animation and sound. Multimedia software with user-friendly inter-faces were instrumental in bridging the gap between technologists and historians in architectural education.

It can be argued that the coupling of design methods with the power of computing has brought about the first radical change in how we design buildings since the renaissance discovery of perspective geometry.

The impacts can be summarised thus:

- of all the design professions, it can be argued that architecture has led the way in the effective adoption of the emerging information technologies; just as developments in artificial intelligence, however primitive, have informed an understanding of the sophistication of the human mind, so CAAD has informed our understanding of the complex human activity of design.
- the application of the technologies to the cultural issues that are central to the concerns of the profession (eg virtual heritage), and to our understanding of the relationship across the range of scale of operation of the profession – from interior design to the design of individual buildings, through neighbourhoods to cityscapes offers, in the words of Frank Ghery in his acceptance speech on receipt of the RIBA Gold Medal, "a great opportunity for architects to become master builders again"..
- the extraordinary advances in verisimilitude of the still and animated imaging of the visual characteristics of interiors and exteriors of individual building and entire neighbourhoods, surely gives, as never before, confidence to practitioners and their clients that what is intended, aesthetically, is what

will be delivered.

- the power of advanced dynamic models of the thermodynamic behaviour of buildings, in response to diurnal and seasonal variation in weather and climate, has the potential to save millions of Euro, and, more importantly in the long run, dramatically reduce atmospheric and stratospheric pollution; these models have the potential to provide us with a new *vernacular of sustainability.*
- the recent emergence of robust and powerful decision support systems that allow synchronous design across continents, time-zones, professions and agencies will enable the next generation of architects and engineers to design from *within* the virtual world which links virtual reality to rapid manufacture and shape grabbing technologies in a seamless transition amongst modelling options.
- the establishment of a number of hugely effective and inter-related initiatives to secure and promote communication within and across academia and practice viz: the formation in Europe of eCAADe (http://www.ecaade.org), in North America of ACADIA (http://www.acadia.org), in South America of SIGRADI (http://www.sigradi.org), in SE Asia of CAADRIA (http://www.caadria.org), in the Arab Regions of ASCAAD (http://ascaad.org) and, internationally, of CAAD Futures (http://www.caadfutures.org), complemented by the meticulously maintained CUMINCAD database of over 10,000 abstracts/papers in the subject area (http://cumincadscix.net); and, last but not least, the initiative to bring into existence the International Journal of Architectural Computing (http://www.architecturalcomputing.org). These initiatives are quite unprecedented in the architecture profession and, herald a new model for cooperation and consensus in the academic and professional community.

The multiple ways in which ICT is impacting architectural practice and education were summarised in a presentation (Figure 4) by Maver and DiMascio to the Mackintosh School of Architecture at the Glasgow School of Art (Maver and DiMascio, 2014).

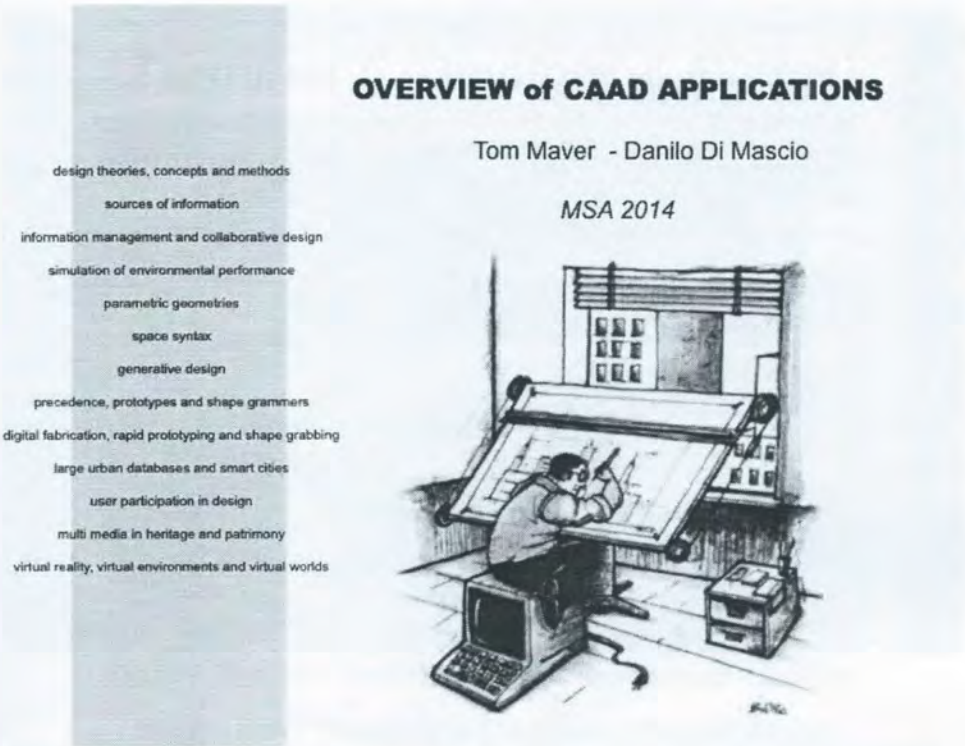

Figure 4. An overview of the range of CAAD applications in 2014

An alternative way of summarising the current state-of-the-art is to consider the portfolio of progressive CAAD consultancy companies; one such is IES (Integrated Environmental Systems) that was spun-out from the academic research group ABACUS. IES now employs some 150 specialist staff in offices in its head-quarters in Glasgow (UK) and in Dublin (Ireland), Boston (USA), Vancouver (Canada), Puna (India) and Melbourne (Australia).

Over the last 20 years, IES has become well known globally for its innovation and expertise in creating early stage to detailed building performance analysis tools, as well as the provision of related consulting specialist services to achieve truly sustainable, low energy and comfortable buildings.

Figures 5,6,7 and 8 give some idea of the highly graphical analyses to assist architects, engineers and building owners/managers in the achievement of more economical, functional and sustainable buildings.

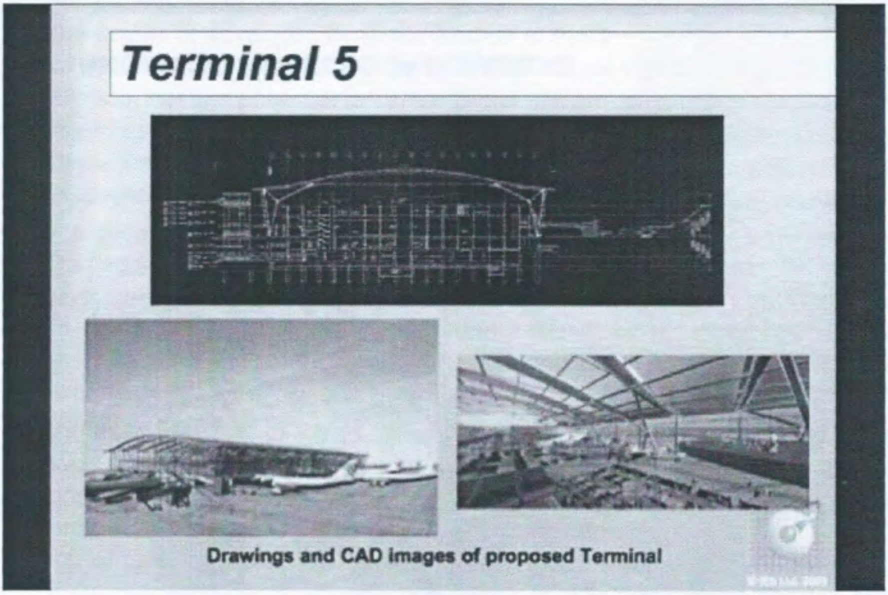

Figure5. Terminal 5 Heathrow Airport, London: CAAD images

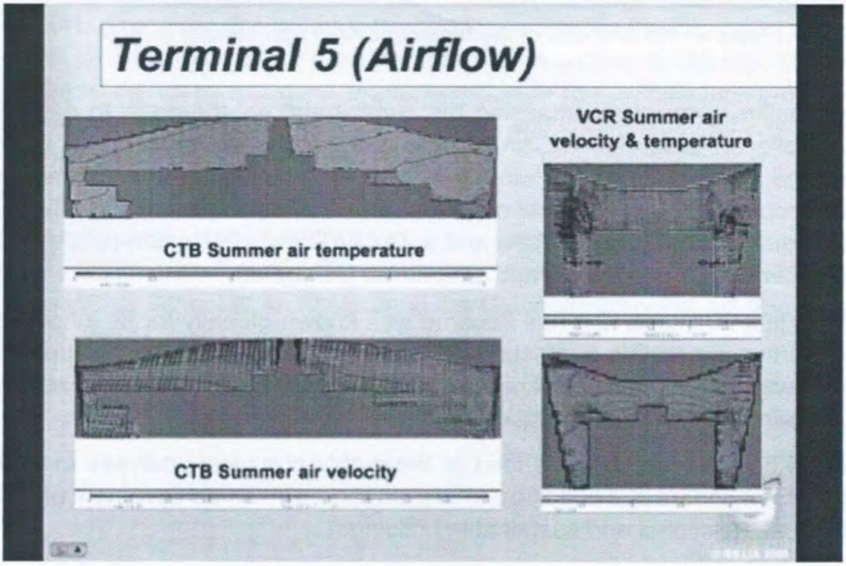

Figure 6. Terminal 5 Heathrow Airport: airflow analysis predicting air velocity and temperature

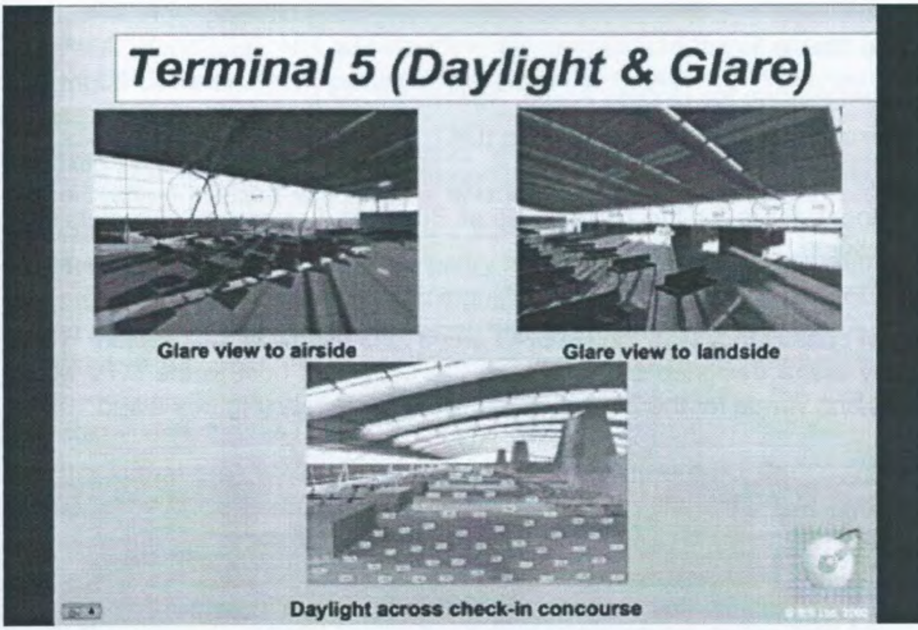

Figure 7. Terminal 5 Heathrow Airport : daylight and glare analysis

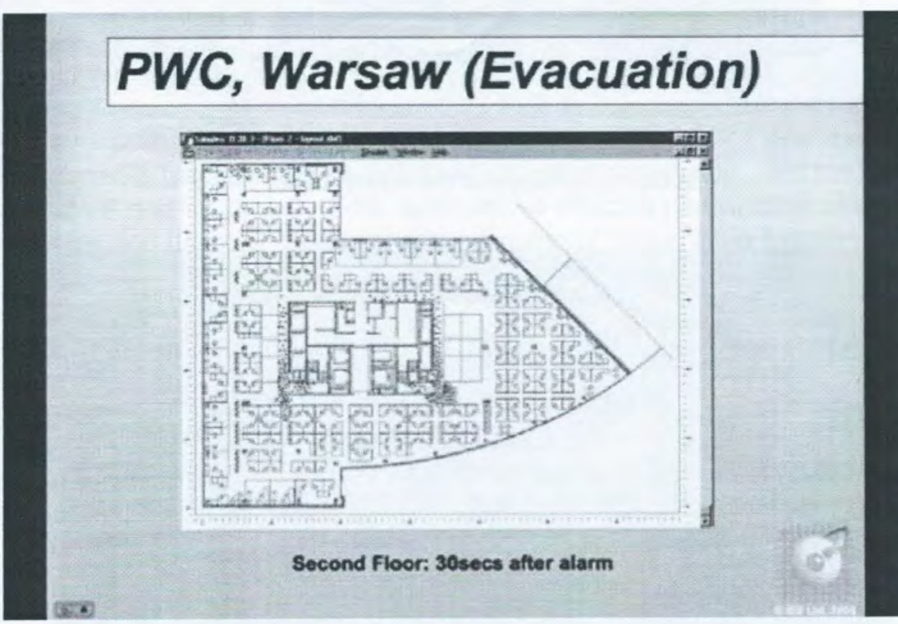

Figure 8. Headquarters for PWC, Warsaw: evacuation simulation following fire alarm

Sports facilities, auditoria and arenas are amongst the building types in the IES portfolio. These include:

- Bridgestone Ice Hockey Arena, Nashville (USA)
- Excel Exhibition Centre, London (UK)
- Edmonton Ice Hockey Arena Edmonton (Canada)
- Sports Halls for the Universities of Bradford, Leicester, Lancaster, et al (UK)

A recent consultancy was the HYDRO arena in Glasgow, a $200miilion , 13,00 capacity arena designed by Foster and Partners and host to the MTV Music Awards and venue for the 2014 Commonwealth Games. (Figures 9 and 10).

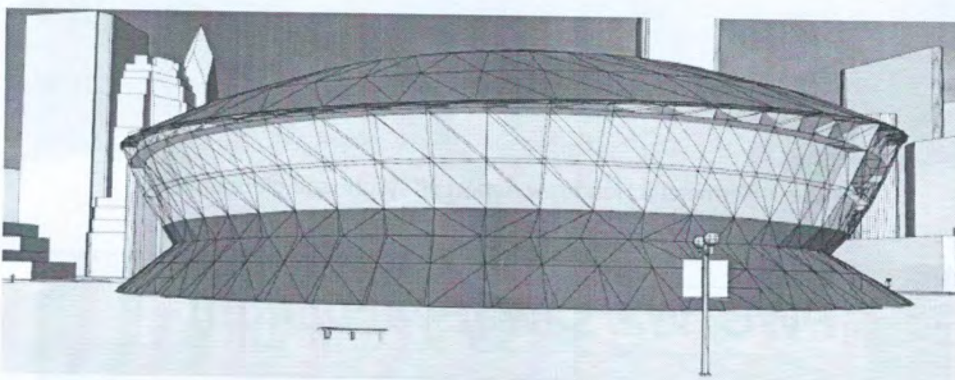

Figure 9. Computer model of the Hydro Arena, Glasgow

Figure 10. Photograph of the completed Hydro Arena

> "The architecture of cyberspace will succeed where modern architecture failed. Utopian imagination is no longer limited by physical reality. Its only limitation is the speed of rendering engines. The dream of transporting people through the experience of space can finally become a reality."
> ".... an architecture without doors and hallways, where the next room is always where I need it to be. Liquid architecture makes liquid cities that change at the shift of a value, where visitors with different backgrounds see different landmarks, where different neighbourhoods vary with ideas held in common, and evolve as the ideas mature and dissolve."

In conclusion, it can be said that members of the CAAD community – academic staff, students and practitioners – have been privileged to share, over four exciting decades, a part in a truly transformational change in architectural research, teaching and practice. What has taken place may, however, represent only the first faltering steps in our amplification of the intellect. Those who choose to take the subject forward in the *next* four decades, will be privileged indeed.

Charles Babbage, working in 1833 on the first mechanical programmable computer with his muse and colleague, the mathematician Ada Lovelace, prophetically offered to give up the rest of his young life if he could come back in 100 years time, for one day only, to see how the idea of computing had worked out; it's application to the complex and important areas of sustainable, innovative and virtual architecture would surely have convinced him that the deal was worthwhile!

References

1. Archer, B. (1976). In a lecture entitled: The Three R's at the Manchester Regional Centre for Science and Technology.
2. Clarke, J.A., Maver, T.W. (1991). Advanced Design Tools for Energy Conscious Building Design: Development and Dissemination. Building and Environment, 26(1), 25-34.
3. Jones, J.C. (1970). Design Methods. Wiley: Pergamon Press, 1992 Building Science, 4, 299-207.
4. Markus T.A. et al. (1972). Building Performance. Applied Science Publishers.
5. Maver, T.W. A. Theory of Architectural Design in Which the Role of the Computer is Identified. Building Science, Pergamon Press, 4, 199-207.
6. McElroy, L. et al. (1997). Experiences from a Design Service Using Simulation. Proc. Building Simulation '97, Prague.
7. Negroponte, N. (1970). The Architecture Machine: Towards a More Human Environment. Cambridge MA, MIT Press.
8. Simon, H. (1968). The Sciences of the Artificial. Cambridge MA, MIT Press.